

p-Adic description of Higgs mechanism V:
New Physics

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Abstract

This is the fifth paper in the series devoted to the calculation particle and hadron masses in the p-adic field theory limit of TGD. In this paper the possibility of two new branches of physics suggested by TGD, namely M_{89} hadron physics and M_{127} lepto-hadron physics, is considered. According to TGD leptons and U type quarks have colored excitations. The anomalous production of e^+e^- pairs in heavy ion collisions indeed suggests the existence of light leptomeson decaying to $e + e^-$ pairs. There are however grave objections against the existence of light exotics. First, asymptotic freedom in the standard sense is lost unless the exotic colored bosons with spin one save the situation. Secondly, Z^0 decay widths seem to exclude light exotic fermions. The solution of the problem is based on p-adic unitarity and probability concepts. In general the real counterpart for the sum of p-adic probabilities differs from the sum for the real counterparts of individual probabilities. The interpretation is that the sum of p-adic decay probabilities corresponds to the situation, where individual final states are not monitored separately but a common signature for final states is used whereas the sum of real probabilities describes the situation, where each final state is monitored separately. An elementary consequence of p-adic unitarity is that the p-adic transition rate for $X \rightarrow \text{anything}$ vanishes for any initial state (as it must since there is no signature for 'anything'), when individual final states are not monitored. The total decay rate of Z^0 to unmonitored exotic leptons (p-adic sum of probabilities!) is very sensitive to the value of $\sin^2(\theta_W(ef\!f))$ and indeed vanishes for $\sin^2(\theta_W(ef\!f)) = 0.23114$! The decays $\mu \rightarrow \pi_L$ and $n \rightarrow p + \pi_L$ afford a unique possibility to detect charged lepton and one obtains upper bound for $W - \pi_L$ coupling. TGD predicts no Higgs particle and M_{89} hadron physics obtained by scaling the old hadron physics mass scale by factor 512 seems to be the TGD:ish counterpart of Higgs necessary to make theory unitary. The anomalies reported in the production and decay of top quark candidate might result from the production of u and d quarks of M_{89} hadron physics having masses very nearly equal to the masses of top candidate. Therefore the signatures of the M_{89} Physics are considered. The concept of topological evaporation suggests the identification of Pomeron as sea in TGD picture.

Contents

1	Introduction	4
2	Exotic bound states of leptons	6
2.1	Relationship between p-adic and real probabilities	7
2.2	Do colored excitations imply the loss of asymptotic freedom?	11
2.3	p-Adic loophole	16
2.4	Colored excitations of leptons	22
2.5	Experimental signatures of leptonhadrons	24
2.5.1	Leptonhadrons and lepton decays	25
2.5.2	Leptonions and beta decay	26
3	Scaled up copies of hadron Physics?	28
3.1	The observed top candidate and M_{89} Physics?	28
3.2	What the New Physics could look like?	30

1 Introduction

p-Adic TGD makes possible surprisingly detailed understanding of elementary particle and hadron masses. Although the hadronic mass formula contains several parameters, which cannot be predicted at this stage one can deduce the values of these integer parameters by number theoretic constraints plus few empirical inputs. TGD differs from standard model in some respects.

a) TGD predicts also some exotic fermions and bosons. Color decuplets ($10, \bar{10}$) of charged and neutral leptons and 27-plet of colored neutrinos as well as color excitations of U type quarks created by color decuplets are predicted. Also exotic colored bosons are predicted in representations $8, 10, \bar{10}$ and 27 . This suggests that asymptotic freedom in standard sense is lost unless spin one colored bosons save the situation. The decay width of Z^0 boson seems also to exclude new light fermions. The observation of e^+e^- pairs in heavy ion collisions, which seem to originate from unknown pseudoscalar meson of mass of order MeV suggest together with esthetic arguments suggest that leptoquarks exist. This suggests the possibility that p-adic unitarity and probability concepts might indeed allow leptoquark physics.

b) In previous paper it was found that hadron masses can be understood within one per cent errors and even isospin splittings can be understood. The only exception was top quark, whose mass for $k(top) = 89$ ($k(top) = 97$) was predicted to be about five times larger (3 times smaller) than the mass of the observed top candidate [Abe *et al*(1994)]. The properties of CKM matrix seem to force the identification of the top candidate as actual top and small mixing of $k = 97$ and $k = 89$ condensate levels gives required mass for top quark. The mass of top candidate is however quite close to the masses of u and d quarks of M_{89} hadron physics and the failure to distinguish between the actual top and u_{89} and d_{89} might explain the reported anomalies in production and decays of the top candidate.

c) The existence of M_{89} hadron physics is suggested by the unitarity requirement also. There is no room for Higgs in TGD and M_{89} hadrons would be the counterpart of Higgs needed to guarantee unitarity.

In the following the possibility of leptoquark physics is considered.

a) It is shown that asymptotic freedom is not lost: this is due to the existence of $J = 1$ exotic colored bosons whose contribution dominates in β

function. The existence of QCD for each Mersenne prime is proposed and color coupling strength $\alpha_s(M_n)$ becomes large (of order $p - 1 + O(p)$) for $\Lambda(M_n)$. Below $(\Lambda(M_n) \bmod p)$ modulo mathematics saves the situation since p-adic color couplings strength as well as beta function are of order $O(p)$ and have extremely small real counterparts, which in practice means the end of that particular QCD.

b) The problem of Z^0 decay widths forces the detailed study of p-adic unitarity and probability concepts and leads to profoundly new ideas concerning physical measurement. The point is that the real counterpart for the sum of p-adic probabilities is not identical with the sum for the real counterparts of individual probabilities. The interpretation is as follows: the p-adic sum of probabilities applies to the measurement, where only a common signature for final states is used whereas the sum for real counterparts of the individual probabilities refers to the situation, where each final state is monitored separately using a specific signature. The idea that measurement situation affects the outcome in this manner is new although physically there is no mysterious in it since the experimental arrangements are completely different.

c) A particular consequence of the p-adic unitarity is that the p-adic probability for $X \rightarrow \text{anything}$ for a given initial state X vanishes. The explanation is simple: there is no experimental signature for 'anything' and therefore even the test of this prediction is impossible.

d) The p-adiction of decay amplitudes squared for gauge bosons shows that its total p-adic probability for Z^0 to decay into exotic leptons in final state can be made very small with the finetuning of the Weinberg angle: also now modulo arithmetics is at work.

e) The decays $\mu \rightarrow \nu_\mu + \pi_L$ and $n \rightarrow p + \pi_L$ provide unique tests for lepton pion hypothesis and expressions for decay rates and bounds for appropriate couplings using CVC and PCAC hypothesis.

The second part of the paper is devoted to the newly interpreted top quark candidate and the possible signatures of M_{89} hadron physics. As found in previous paper CKM matrix seems to favour the identification of the observed top candidate as actual top and one can understand top mass if small condensate level mixing between $k = 97$ and $k = 89$ levels takes place. The mass of top candidate is nearly the same as the masses of u and d quarks of M_{89} Physics. Therefore one can consider the possibility that the production of M_{89} hadrons could explain the reported anomalies in top production

rate. Topological evaporation concept suggests that the newly born concept of Pomeron of Regge theory can be identified as the sea of perturbative QCD. The possibility to identify these basic phenomenological concepts shows the unifying power of TGD framework.

2 Exotic bound states of leptons

TGD predicts colored excitations for leptons and in [Pitkänen and Mähönen, Pitkänen₁] an explanation for the anomalous production of e^+e^- pairs in the collisions of heavy nuclei based on the concept of leptonium was proposed. Leptonium, and more generally, leptonhadrons were assumed to be bound states of color octet excitations of leptons and it was found that generalization of PCAC hypothesis gives even quantitatively satisfactory description for the anomalous e^+e^- production. It is useful to reconsider the hypothesis in light of recent experimental facts.

- a) Empirical constraints do not force the constituents of the resonance decaying to e^+e^- pair to be colored: what is however needed is some confinement mechanism allowing excitations with higher mass. If constituents are colored they need not be necessarily color octets as originally believed to be. If one identifies the resonance as color bound state there are two natural possibilities: the identification as either leptonium or as lepto- η .
- b) A strong empirical constraint on the number of light massless fermions comes from the decay widths of intermediate gauge bosons. The decay width is simply the sum of contributions coming from various light fermions and Z^0 decay width doesn't allow new light fermions. It is difficult to imagine why massless colored leptons should not be regarded as mass elementary fermions and it seems that one must assume that colored leptons and quarks are condensed on level with $p \geq M_{89}$ and one would lose the elegant explanation of anomalous e^+e^- pairs.
- c) Asymptotic freedom is a sacred hypothesis of practically all unified model building and one must find whether the exotic colored $J = 1$ bosons can preserve asymptotic freedom threatened by the existence of exotic fermions.
- d) One can consider also a rather science fictive possibility that p-adic probability might pose only a weaker condition on the numbers of various light fermions via Z^0 decay widths: condition would which the numbers only modulo certain integer so that color excited quarks and leptons could exist peace-

fully. The consideration of this admittedly crazy idea turns out to be very fruitful since it leads to understanding of the relationship between p-adic and real unitarity and probability concepts and gives some foretaste of how deep role number theory plays in the construction of S-matrix. Even more: explicit calculations show that p-adic loophole exists!

2.1 Relationship between p-adic and real probabilities

p-Adic quantum field theory gives rise to transition probabilities P_{ij} , which are p-adic numbers. The first problem is to associate real conserved probabilities to p-adic probabilities. The identification is based on a simple renormalization for the real counterparts of the p-adic probabilities $(P_{ij})_R$ obtained by canonical identification.

$$\begin{aligned}
P_{ij} &= \sum_{k \geq 0} P_{ij}^k p^k \\
P_{ij} &\rightarrow \sum_{k \geq 0} P_{ij}^k p^{-k} \equiv (P_{ij})_R \\
(P_{ij})_R &\rightarrow \frac{(P_{ij})_R}{\sum_j (P_{ij})_R} \equiv P_{ij}^R
\end{aligned} \tag{1}$$

The procedure converges rapidly in powers of p and is highly reminiscent of renormalization of quantum field theories [Pitkänen_b]. The renormalization procedure automatically divides away one four- momentum delta function from the square of S-matrix element containing square of delta function with no well defined mathematical meaning. Usually one gets rid of the delta-function interpreting it as the inverse of the four-dimensional measurement volume so that transition rate instead of transition probability is obtained. Of course, also now same procedure should work either as a discrete or continuous version.

The crucial question is what is the physical difference between the real counterpart for sum of p-adic transition probabilities and for the sum of the real counterparts of these probabilities, which are in general different

$$(\sum_j P_{ij})_R \neq \sum_j (P_{ij})_R \quad (2)$$

There is also a problem of renormalization. The suggestion is that p-adic sum of transition probabilities corresponds to the experimental situation, when one does not monitor individual transitions but using some common experimental signature only looks whether the transition leads to this set of final states or not. When one looks each transition separately or effectively performs different experiment by considering only one transition channel in each experiment one must use the sum of real probabilities. More precisely the choice of experimental signatures divides the set U of the final states to disjoint union $U = \cup_i U_i$ and one must define the real counterparts for transition probabilities P_{iU_k} as

$$\begin{aligned} P_{iU_k} &= \sum_{j \in U_k} P_{ij} \\ P_{iU_k} &\rightarrow (P_{iU_k})_R \\ (P_{iU_k})_R &\rightarrow \frac{(P_{iU_k})_R}{\sum_l (P_{iU_l})_R} \equiv P_{iU_k}^R \end{aligned} \quad (3)$$

The assumption means deep difference with respect to the ordinary probability theory. Physically there is nothing mysterious in the difference since the experimental situations are quite different in two cases. The procedure is even familiar for physicists! Assume that the labels j correspond to momenta. The division of momentum space to cells of given size so that individual momenta inside cells are not monitored separately means that momentum resolution is finite. Therefore one must perform p-adic sum over cells and define real probabilities in the proposed manner. p-Adic effects resulting from the difference between p-adic and real summation are the counterpart to renormalization effects in QFT. It should be added that similar resolution can be defined also for initial states by decomposing them into a union disjoint subsets.

p-Adic probability conservation implies that the lowest order terms for p-adic probabilities satisfy the condition $\sum_j P_{ij}^0 = 1 + O(p)$. The general

solution to the condition is $P_{ij}^0 = n_{ij}$. If the number of the final states is much smaller than p this alternative implies that real transition rates are enormous: typically of order $p!$ Therefore it seems that one must assume

$$P_{ij}^0 = \delta(i, j) \quad (4)$$

As a consequence the probability for anything to happen (no monitoring of different events) is given by

$$\sum_j (P_{ij} - \delta(i, j)) = 0 \quad (5)$$

and vanishes identically! This is not so peculiar as it looks first since there must be some signature for anything to happen in order that it can be measured and signature always distinguishes between two different events at least: it is difficult to imagine what the statement 'anything did not happen' might mean! Of course, in real context this philosophy would imply the triviality of S-matrix.

The unitarity condition implies that the the moduli squared of the matrix T in $S = 1 + iT$ are of order $O(p^{1/2})$ if one assumes four-dimensional p-adic extension allowing square root for p-adically real numbers and one can write

$$\begin{aligned} S &= 1 + i\sqrt{p}T \\ i(T - T^\dagger) + \sqrt{p}TT^\dagger &= 0 \end{aligned} \quad (6)$$

It must be emphasized that this expression is completely analogous to the ordinary one since $i\sqrt{p}$ is one of the units of the four-dimensional algebraic extension. Unitarity condition in turn implies recursive solution of unitary condition in powers of p :

$$\begin{aligned} T &= \sum_{n \geq 0} T_n p^{n/2} \\ T_n - T_n^\dagger &= \frac{1}{i} \sum_{k=0, \dots, n-1} T_{n-1-k} T_k^\dagger \end{aligned} \quad (7)$$

If algebraic extension is not allowed then the expansion is in powers of p instead of \sqrt{p} . Note that the real counterpart of the series convergences extremely rapidly.

Before one is able to p-adicize decay rates of gauge bosons one must solve some problems related to the transition from p-adic to real realm. In order to obtain transition rates one must integrate p-adically over the final state momenta. The ordinary real integration measure

$$dV_f = (2\pi)^4 \prod_{i=1}^{N_f} \frac{d^3 p_i}{2E_i (2\pi)^3} \quad (8)$$

is problematic due to the appearance of powers of π since it is not at all obvious what π means p-adically. The solution of the problem is the necessary appearance of p-adic infrared cutoff, which means that summation is performed instead of integration and everything is rational. The decay rates contain also the factor $1/2M(B)$ and this need not be rational nor even p-adically real number. Same applies to the flux factor appearing in cross sections.

The practical solution of these problems is based on physical argument. One has could reasons to argue that in good approximation final state momenta belong to state labels, for which monitoring is performed for each momentum value separately so that the integration over the final state momenta must be performed on the real side so that the problems related to powers of π disappear totally. In this case it is $|M|^2$, which is the correct p-adic quantity to study and for a given momentum configuration one can still perform p-adic sum over the degrees of freedom not monitored. Assuming that the squares g_i^2 of coupling constants and other analogous parameters are rational numbers and also that four-momenta are rational (by the necessary infrared cutoff) $|M|^2$ is indeed rational number.

The proposed interpretation for p-adic probabilities suggests a new formulation of renormalization theory. It is convenient to use spacetime picture, spacetime points being defined as p-adic space dual to the momentum space. Finite resolution means division of the p-adic spacetime into cells of given size so that no monitoring of individual points inside cell is performed: this implies effective momentum cutoff. A nice feature is that if cell size is defined

using p-adic norm space time decomposes into disjoint regions in p-adic case (ultrametricity [Pitkänen_b]). The theories associated with different cell sizes correspond to different physical situations and renormalization is therefore not a mere calculational tool. Transition rates are obtained by summing the p-adic transition probabilities p-adically over each cell associated with final state spacetime points, averaging over initial state space time points over each cell, mapping the result to reals and performing the needed renormalization for the real probabilities. Momentum space description is obtained by taking Fourier transform for each incoming and outgoing particle. Infinitesimal renormalization operation corresponds to the change in transition probabilities induced by a change in the resolution scale so that generalized beta functions can be defined in terms of the derivatives with respect to the length scale for the real counterparts of the integrals over momentum space cell volume. The real valued running couplings constants involving logarithms $\ln(Q^2/Q_0^2)$ result basically from the change of the physical situation, when the length scale $L = 1/Q$, below which no monitoring is carried out changes. p-Adically the logarithms do not even make sense for all momenta.

p-Adic probability concept provides an elegant solution to the infrared divergence problems of the gauge theories. The measurement of scattering rates of say two charged particles in forward directions, where real transition rates diverge and lead to infinite cross section in real QED, is limited by angular resolution. This means that one cannot monitor individual events in certain small cone around forward direction and total rate for this small cone is obtained by summing p-adic probabilities for the cone in question and mapping the sum to the reals. The total p-adic rate is however always of form $P(if) = Xp + \dots$, where X cannot increase above p so that total rate remains finite.

2.2 Do colored excitations imply the loss of asymptotic freedom?

The most spectacular consequence of the existence of colored excitations would be the loss of asymptotic freedom in the conventional sense of the word for both leptohadrons and ordinary hadrons. In the real theory the beta function corresponds to the sum over fermion and gluon loops for gluon propagator

$$\begin{aligned}
\alpha_s(Q^2) &\simeq \frac{\alpha(Q_0^2)}{(1 + \alpha_s(Q_0^2) \frac{b_0}{4\pi} \ln(Q^2/Q_0^2))} \\
b_0 &= \frac{11}{6}l(J=1) - \frac{2}{3}l(J=1/2) - \frac{1}{12}l(J=0) \\
l(J) &= \sum_{light(D,J)} l(D,J)
\end{aligned} \tag{9}$$

Where the total index $l(J)$ associated with spin J particles is sum over the indices of color representations D with spin J . Fermions are assumed to be Dirac fermions. Summation is over the colored elementary particles, which are light in mass scale Q_0^2 .

The list for the values of the indices $l(D)$ for the representations in leptonic $(10, \bar{10}, 2 \times 27)$ and quark sector $3 \otimes (10 + \bar{10}) = 15 + 15' + 6 + 24$ is given in table below. The second table lists exotic colored bosons for $T = 1$ and $T = 1/2$ and the remaining tables give the contribution of single exotic generation to b_0 and asymptotic value of b_0 for $T = 1$ and $T = 1/2$.

lepton N	$n(N)$	$l(N)$	$C(N)/C(3)$	quark N	$n(N)$	$l(N)$	$C(N)/C(3)$
10	1	15	$\frac{9}{2}$	15	1	20	4
10	1	15	$\frac{9}{2}$	15'	1	35	7
27	2	54	6	6	1	5	$\frac{15}{2}$
				24	1	50	$\frac{25}{4}$

Table 2.1. The degeneracies $n(N)$ of color representations and so called index $l(N)$ of the representation for the exotic leptons and quarks. The table contains also the values of Casimir operators needed later.

spin	charge operator	D	$n(D)$	$M^2(T = 1)$	$M^2(T = 1/2)$
0	$I^\pm Q_K$	8	1	$\frac{2}{p}$	0
1	I^\pm	8	1	Planck mass	$\frac{1}{2p}$
1	$I_{L/R}^3 Q_K$	8	1	Planck mass	$\frac{1}{2p}$
1	$I^\pm Q_K$	8	1	Planck mass	$(\frac{3p}{10})_R \frac{1}{p}$
0	$I^\pm Q_K$	10, 10	1	$\frac{3}{p}$	0
0	1	10, 10	1	0	0
1	I^\pm	10, 10	1	$\frac{3}{p}$	0
1	$I_{R/L}^3 Q_K$	10, 10	1	$\frac{3}{p}$	0
0	I^\pm	27	1	Planck mass	$\frac{1}{2p}$
0	$I_{R/L}^3 Q_K$	27	1	Planck mass	$\frac{1}{2p}$
1	$I_{R/L}^3$	27	1	Planck mass	$\frac{1}{2p}$
1	Q_K	27	1	Planck mass	$\frac{1}{2p}$
0	$I_{R/L}^3$	27	2	0	0
0	Q_K	27	2	0	0
1	1	27	2	0	0

Table 2.2. Charge operators, degeneracies and masses of colored exotic bosons for p-adic temperature $T = 1$ and $T = 1/2$. The last two massless bosons are doubly degenerate due to occurrence of two 27-plets with conformal weight $n = 2$.

T	$\Delta b_0(B)$	$\Delta b_0(q)$	$\Delta b_0(L)$
1	$230 - 1/2$	-112	$-\frac{220}{3}$
$\frac{1}{2}$	$639 - 1/2$	-112	$-\frac{220}{3}$

Table 2.3. Contributions of single exotic fermion and boson family to the coefficient b_0 for p-adic temperature $T = 1$ and $T = 1/2$.

T	n(boson family)	$b_0(h)$	$b_0(L)$
1	1	$11 - \frac{2n_f}{3} + 230 - \frac{1}{2} - 220$	$11 + 230 - 1/2 - 336$
1	3	$11 - \frac{2n_f}{3} + 689 - \frac{1}{2} - 220$	$11 + 689 - 1/2 - 336$
$\frac{1}{2}$	1	$11 - \frac{2n_f}{3} + 639 - 1/2 - 220$	$11 + 639 - 1/2 - 336$
$\frac{1}{2}$	3	$11 - \frac{2n_f}{3} + 1916 - 1/2 - 220$	$11 + 1916 - 1/2 - 336$

Table 2.4. Asymptotic values of b_0 for hadronic and leptohadronic gluons for $T = 1$ and $T = 1/2$ and for single and 3 exotic boson families respectively. The standard contribution to b_0 is written separately.

Some general conclusions can be made by inspecting these tables.

a) It seems natural to assume [Pitkänen_b] that each different QCD (one for each Mersenne prime) has its own gluons and colored bosons and that confinement makes the direct communication between different QCD:s impossible (gluons of M_{8107} QCD do not couple to quarks of M_{89} QCD). The assumption implies that colored lepton pairs are not produced in hadronic reactions via gluon emission.

b) In TGD one expects family replication phenomenon for bosons, too. All $g > 0$ bosons are massive and the modular contribution to mass squared is same as for fermions and dominates. Family replication implies asymptotic freedom even for $T = 1$. $T = 1/2$ alternative is probably excluded since it implies too rapid coupling constant evolution. For $T = 1$ asymptotic freedom achieved in leptonic sector with 2 boson generations whereas one boson family is enough in hadronic sector. Coupling constant evolution is sensitive to the masses of exotics and therefore to the topological mixing of exotic fermions and bosons.

c) The massless ($J = 1, g = 0$) 27-plet gives the dominating $J = 1$ contribution to beta function and implies extremely rapid coupling constant evolution. In case of hadrons this possibility is definitely excluded. Catastrophe is avoided if $g = 0$ multiplet suffers topological mixing with $g > 0$ 27-plets and becomes massive.

d) In case of hadrons there seems to be no place for light exotics. The first possible primary condensation level for exotic bosons and quarks seems to be M_{89} : otherwise the exotic bosons and fermions should have been seen in e^+e^- annihilation to hadrons: also hadrons having exotic quarks as constituents would have been observed. Color coupling evolution becomes very rapid after first exotic boson generation unless all exotic fermions and first generation bosons have nearly identical masses. Note that the masses of first generation exotic U quarks suffered primary condensation on M_{89} level have mass essentially identical to the mass of the observed top candidate and could also contribute to the signal besides u and d quarks of the M_{89} hadron physics.

The previous considerations are based on experience with ordinary real QFT. The problem is to understand what is the p-adic counterpart of the

real coupling constant evolution.

a) p-Adic logarithms $\ln(Q^2/Q_0^2)$ appearing in the expressions of running coupling constants exist only provided the condition

$$\frac{Q^2}{Q_0^2} = 1 + O(p) \quad (10)$$

holds true. This suggest that in p-adic theory one has distinct coupling constant evolution in each cell

$$\begin{aligned} Q^2 &= Q^2(k, n) + O(p) \\ Q^2(k, n) &= np^k \\ g^2(Q^2) &= g(Q^2(k, n)f(\ln(\frac{Q^2}{Q^2(k, n)}))) \end{aligned} \quad (11)$$

The result implies that there exist in principle two distinct coupling constant evolutions. One is related to the changes of the initial value $g^2(Q^2(k, n))$ as function of cutoff scale $Q^2(k, n)$ and one evolution inside each 'cell' (k, n) .

b) p-Adic conformal field theory describes critical system: this suggests that beta functions should vanish identically and coupling constant evolution inside each cell (k, n) ought to be trivial. This in turn would mean that ordinary coupling constant evolution is replaced with stepwise jumps of the coupling strenght $g^2(k, n)$ and it is this evolution, which has as real counterpart the ordinary logarithmic coupling constant evolution. The unpleasant consequence is that the argument leading to $Q^2(k, n)$ is lost. Cell structure might well follow from the fact that p-adically analytic functions of Q^2 appearing in S-matrix elements converge only inside cells (k, n) .

c) The divergence of the coupling constant strength is not possible in p-adic theory. The largest possible value is achieved, when one has

$$g_{max}^2 = (p-1)(1+p+p^2+\dots) = -1 = p-1 + O(p) \quad (12)$$

What is remarkable is that if evolution continues the next step corresponds to $g^2 \rightarrow g_{max}^2 + 1 = O(p)$ so that the real counterpart of the coupling strength

becomes extremely small, of the order of gravitational coupling strength in dimensionless units! Also beta function is of order $O(p)$ after this jump. This means the end of the QCD in question.

This general picture fits nicely into the concept of p-adic length scale hierarchy. Various QCD:s in the hierarchy of QCD:s correspond to Mersenne primes M_n and color coupling strength becomes extremely small below $\Lambda(M_n)$. One cannot exclude the possibility that exotic bosons are much more massive than exotic fermions and asymptotic freedom' with extremely small color coupling strength sets on outside the finite range $[\Lambda(M_n), lower), \Lambda(M_n, upper)]$.

The fact that bosons determine coupling constant evolution near $\Lambda(M_n)$ plus fractality considerations suggest that the scales $\Lambda(M_n)$ are universal and of form

$$\Lambda(M_n) = \frac{k}{\sqrt{M_n}} \quad (13)$$

For leptonhadrons the hypothesis implies $\Lambda(M_{127}) = 2^{-10} \Lambda_{QCD} \simeq 0.3 \text{ MeV}$ for $\Lambda_{QCD} \simeq 310 \text{ MeV}$. With same assumption one has $\Lambda(M_{89}) = \frac{M_{89}}{M_{107}} \Lambda(QCD) \simeq 158.7 \text{ GeV}$, which means that the observed top quark candidate could belong to M_{89} Physics.

2.3 p-Adic loophole

Intermediate gauge bosons exclude light exotic particles in standard model and the predictions of the standard model are in excellent agreement with experiments. One can ask whether p-adic probability concept might allow room for new light exotics. The point is that in p-adic context the transition probabilities $P(i \rightarrow j)$ satisfy the condition $\sum_j (P(i \rightarrow j) - \delta(i, j)) = 0$ p-adically. In case of decay rates this means that system is stable if one only looks whether system decays but does not monitor specific decay channels. When one looks for specific decay channels the system is found to decay. The squares of p-adicized decay amplitudes for intermediate gauge bosons are indeed of order $O(p^2)$ so that the possibility that the total p-adic decay rate to unmonitored exotic channels can be very small and light exotic leptons and quarks are therefore possible.

In order to see that p-adic effects can solve the problem posed by gauge boson decay widths, one can naively p-adicize the squares of the decay amplitudes of intermediate gauge bosons: by the simplicity of the process these quantities are expected to be quite universal in their dependence on various parameters. The explicit expressions for the squares of the decay amplitudes to the standard channels are in the approximation, when radiative corrections are not included given by

$$\begin{aligned}
|M(W \rightarrow L\bar{\nu}_L)|^2 &= |M(W \rightarrow U\bar{D})|^2 \equiv |M(W)|^2 \\
&= g_{ew}^2 m(W)^2 = g_{ew}^2 X(W) p^2 \equiv Y(W) p^2 \\
|M(Z \rightarrow \nu_e \bar{\nu}_e)|^2 &\equiv |M(Z)|^2 \\
&= \frac{g_Z^2}{2} m(Z)^2 = \frac{g_{ew}^2}{(1-P)^2} X(W) p^2 \equiv Y(Z) p^2 \\
|M(Z \rightarrow e\bar{e})|^2 &= (1 - 4P + 8P^2) |M(Z)|^2 \\
|M(Z \rightarrow U\bar{U})|^2 &= 3(1 - \frac{8P}{3}) |M(Z)|^2 \\
|M(Z \rightarrow D\bar{D})|^2 &= 3(1 - \frac{4P}{3}) |M(Z)|^2 \\
P &= \sin^2(\theta_W)
\end{aligned} \tag{14}$$

These quantities are of order $O(p^2)$, which is due to the fact that gauge boson masses are of order $O(p^2)$. This implies that the real decay rates are of correct order of magnitude provided the coefficient of p^2 is rational number different from integer: integer part of this coefficient gives totally negligible contribution to the decay rate.

The occurrence of additional powers of p is in accordance with the previous observation that P_{ij}^0 is nonvanishing for forward scattering only. This means that the sum of p-adic decay probabilities is vanishing. Intermediate gauge bosons are p-adically stable against decay to anything and unstable against decay to monitored channels! This is possible if the denominators of the coefficients $Y(W)$ and $Y(Z)$ are small integers so that modulo mathematics comes in game, when one sums contributions over different non-monitored channels p-adically. This is indeed the case since the values of g_{ew}^2 and g_Z^2 are of order one $1/2$ and $X(W)$ and $X(Z)$ are apart from renormalization corrections given by $X(W) = 1/2$ and $X(Z) = 1/5$.

This means that the sum over a fairly small number of unmonitored decay channels gives extremely small real decay rate.

Consider next the mechanism at a more detailed level.

a) Weinberg angle and electromagnetic coupling e^2 appear in the decay rate. In calculating decay rates of gauge bosons one must use the effective value of Weinberg angle taking into account various radiative corrections. From LEP precision experiments [Schaile] one has $P_{eff} \simeq 0.2324 \pm 0.0005$. If $e^2 \simeq 0.091701$ rational number, which is a finite sum of finite number of powers of two it behaves like real number in the canonical identification of transition amplitudes squared for Mersenne primes but not in general. It is quite conceivable that the real counterpart of e^2 is much larger (or smaller) for general p-adic prime than for Mersenne primes and this perhaps explains why Mersenne primes are in favoured position dynamically. In a good approximation one has $e^2 = 47/512$ at low energies. In intermediate boson mass scale the renormalized value of $\alpha_{em}(m(Z)^2) \simeq 128.87$, which in good approximation corresponds to $e^2 = 50/512$, implies sizable correction to the decay rate.

b) The numerical values of $Y(W)$ and $Y(Z)$ for LEP value $P_{eff} = 0.2324$ and $e^2(m(Z)^2)$

$$\begin{aligned} Y(W) &= 0.2097 \\ Y(Z) &= 0.1780 \end{aligned} \tag{15}$$

If the coefficients $Y(W)$ and $Y(Z)$ are in a sufficiently good approximation finite sums of negative powers of two the real counterparts of decay rates to single channel are near the values predicted by standard model. It should be noticed that the if the values of $Y(B)$ would have been larger than one the p-adic scenario would not make sense since p-adic scenario predicts that the coefficients are not larger than one. From the values of $Y(W)$ and $Y(Z)$ its clear that the p-adic effects become important, when the number of individually unmonitored channels is larger than 5 so that p-adic modulo effects are bound to affect crucially the total decay rates of Z and W .

c) The naive manner to take into account QED and QCD renormalization corrections is to p-adicize the corrections predicted by real theory

$$\begin{aligned}
|M(W \rightarrow L^{10} \bar{\nu}_L^{10})|^2 &= 10X(10)|M(W \rightarrow e \bar{\nu}_e)|^2 \\
|M(Z \rightarrow F^N \bar{F}^N)|^2 &= NN(Q(F), N, \alpha_s)|M(Z \rightarrow F \bar{F})|^2 \\
N(Q(\nu), N, \alpha_s) &= X(N, \alpha_s)(1 + Q^2(F) \frac{3\alpha_{em}(0)}{4\pi}) \\
X(N, \alpha_s) &= 1 + \frac{C(N)}{C(3)} \frac{\alpha_s}{\pi}
\end{aligned} \tag{16}$$

Here $Q(F)$ is the electromagnetic charge of final state fermion and N refers to color representation. The values of Casimir operators have been listed earlier. The problematic feature is the nonrationality of the variable α_s/π . This results from the sum over the momenta of final state gluons on 'real side'. Actually these gluons are not monitored and sum must be done 'on p-adic side' so that rational number results. Instead of π a rational number near π and expressible as a finite sum of powers of 2 is assumed to result from summation.

d) Z^0 decay rate is affected by the presence of unmonitored exotic leptons as well as exotic U type quarks. For leptons the value of $\alpha_s(L, M_Z)$ can be evaluated by requiring that coupling constant diverges, say, at $2^{-19}M_Z$. This gives $\alpha_s(L, M_Z) \sim 0.0013$. For quarks one can use value near the LEP value $\alpha_s(M_Z) = 0.115 \pm .005$. The p-adic sum over amplitudes squared over exotic leptons depends also on the value of effective Weinberg angle, whose LEP value is 0.2234.

e) The total decay rates to exotic channels for single fermion generation can be derived from the knowledge of colored excitations of quarks and leptons. Assuming that top quark and its exotic partners do not contribute to the exotic decays one has for single fermion generation

$$\begin{aligned}
\sum |M(W \rightarrow L^{10} \bar{\nu}_L^{10} + 10 \leftrightarrow \bar{10})|^2 &= 20X(10, \alpha_s(L))Y(W)p^2 \\
\sum |M(Z \rightarrow \text{exotic neutrinos})|^2 &= (54N(0, 27) + 20N(0, 10, \alpha_s(L)))Y(Z)p^2 \\
\sum |M(Z \rightarrow \text{exotic charged leptons})|^2 &= 20(1 - 4P_{eff} + 8P_{eff}^2)N(1, 10, \alpha_s(L))Y(Z)p^2 \\
\sum |M(Z \rightarrow \text{exotic quarks})|^2 &= \sum_{N=15, 15', 6, 24} NN(\frac{2}{3}, N, \alpha_s)(1 - \frac{8P_{eff}}{3})Y(Z)p^2
\end{aligned} \tag{17}$$

f) The total decay width for W boson is not a measured directly but deduced from the total width of Z^0 . so that the only single experimental constraint comes from the total Z^0 decay width. Z^0 decay amplitudes to exotic leptons and quarks squared should separately sum to a very small contribution. Assuming for Weinberg angle to the LEP value $P = 0.2324 \pm 0.0005$ and by choosing leptonic color coupling strength to be $\alpha_s(L, M_Z) = 0.0010518$ one has

$$\begin{aligned} \sum |M(W \rightarrow \text{exotics})|^2 &= 4.202p^2 \equiv 0.202p^2 \\ \sum |M(Z \rightarrow \text{exotic leptons})|^2 &= 45.00002p^2 \equiv 0.00002p^2 \end{aligned} \quad (18)$$

The value of $\alpha_s(L)$ is in accordance with the estimate obtained from evolution equation with three families of exotic bosons. W total unmonitored width corresponds approximately to single $L\bar{\nu}_L$ channel and this prediction provides a test of the scenario. Also the decay width to the $U\bar{U}$ type exotic pairs should be small if these states are light. Miraculously, for $\alpha_s(m_Z) = .116035$, which is within experimental uncertainties equal to LEP value $\alpha_s(m_Z) = 0.115 \pm .005$, the decay width is of order 10^{-5} if final state contains 1,2 or 3 generations of exotic U quarks. Frustratingly, this miracle is not needed if colored quark and boson exotics suffer primary condensation at level M_{89} !

Exotic leptons poses should be seen in e^+e^- annihilation, too. At low energies the coupling via one photon intermediate state vanishes due to the conservation of vector current but at relativistic energies the situation is different. The production cross amplitude squared for $F\bar{F}$ pair in QED at relativistic energies reads as

$$|M(e^+e^- \rightarrow F\bar{F})|^2 = \frac{e^4}{16}(1 + \cos^2(\theta)) \quad (19)$$

where θ is the angle between incoming and outgoing fermion. The real counter part of the p-adicized expression yields enormous production rate since p-adic rational number is in question. The correct expression must contain additional power of p and does it by previous definition of S-matrix

$$|M(e^+e^- \rightarrow F\bar{F}, p\text{-adic})|^2 = \frac{e^4}{16}(1 + \cos^2(\theta))p \simeq .52 \cdot 10^{-3}(1 + \cos^2(\theta))p \quad (20)$$

If e^2 is finite sum of powers of 2 (same applies to $\cos^2(\theta)$) the real counterpart of this expression is essentially the real production amplitude squared.

At first glance it seems that modulo effects cannot make production rate small since the total p-adic rate to exotic unmonitored final states taking into account all exotics except top is only by a factor 110 larger than the rate to single exotic channel. On the other hand, p-adic unitarity requires that total p-adic transition rate must vanish. The crucial question is the following: does the p-adic total transition rate vanish separately for exotic final states and ordinary final states? If so then exotic channels sum up to zero. The large value of the color correction factor in e^+e^- annihilation rate is in first order approximation given by

$$\begin{aligned} |M|^2 &\rightarrow X(N)|M|^2 \\ X(N) &= 1 + \frac{C(N)}{C(3)} \frac{\alpha_s(L)}{\pi} \end{aligned} \quad (21)$$

provides an attractive mechanism for realizing p-adic unitary for exotic channels separately in the energy region, where $\alpha_s(L)$ becomes large. For ordinary e^+e^- final states scattering the vanishing of sum should due to the p-adic summation over momentum degrees of freedom and the large value of the transition amplitude squared in forward direction coming from Coulomb scattering should play central role in the mechanism.

To summarize, the p-adicized decay amplitudes squared for intermediate gauge bosons are of order $O(p^2)$. This means that total p-adic decay rate vanishes, when individual decay channels are not monitored. The decay rates to single channel are so near to their maximum values that for a p-adic sum over several nonmonitored channels modulo effects become important. The p-adic sum of Z^0 decay rates to unmonitored exotic colored channels is sensitive to radiative corrections and with a fine tuned value of effective Weinberg angle it vanishes.

2.4 Colored excitations of leptons

One can imagine several scenarios explaining the anomalous e^+e^- pairs if one gives up the assumption that constituent fermions for leptonhadrons are massless states and allows tachyonic constituents. If only massless states are allowed then there is only one scenario, which assumes light exotic elementary fermions and requires p-adic probability theory to cope with the constraints coming from intermediate gauge boson decay widths. The table shows that leptons allow decuplet color representations as massless states. Neutrinos allow also two 27 dimensional massless representations and U type quarks allow decuplet representations. Therefore one might think that color excited leptons correspond to $10, \bar{10}, 2 \times 27$ rather than octet representations according to the original belief.

fermion	D(0)	D(1)	D(2)	$\frac{M_R}{m_e \sqrt{\frac{M_{127}}{p}}}$
e^{10}	2	12	40	$\sqrt{\frac{9}{5+\frac{2}{3}}}$
$\nu^{10}, \nu^{\bar{10}}$	12	40	80	1
ν^{27}	2	12	40	$\sqrt{\frac{9}{5+\frac{2}{3}}}$
$U^{10}, U^{\bar{10}}$	2	12	40	$\sqrt{\frac{9}{5+\frac{2}{3}}}$

Table 2. Degeneracies and masses of colored exotic fermions.

The values of lepton masses for decuplet representation (color magnetic and Coulombic forces are not taken into account) are:

$$\begin{aligned}
 m(\pi_L^-) &= \sqrt{\frac{14 + \frac{2}{3}}{5 + \frac{2}{3}}} m_e \sqrt{\frac{M_{127}}{p}} \\
 m(\pi_L^0) &= \sqrt{\frac{18}{5 + \frac{2}{3}}} m_e \sqrt{\frac{M_{127}}{p}}
 \end{aligned}
 \tag{22}$$

The mass of the leptonhadron assumed to explain anomalous e^+e^- production should be roughly equal to $2m_e$: pseudoscalar nature of the resonance allows

the original identification as leptonion or as the leptonic counterpart of η meson. The precise prediction of leptonion mass is not possible at this stage but one can develop consistency arguments.

a) Hadronic case suggests that topological mixing makes $s(\nu^{10})$ and $s(e^{10})$ identical and therefore not smaller than $s_{min} = s(e^{10}) = 9$. The simplest assumption is $s_{eff}(\nu^{10}) = 9$ as in hadronic case: this implies that the mixing matrix for e^{10} is trivial and for ν^{10} the matrix could be equal to the matrix D . for D-type quarks since the change in mass squared is same. The absolute upper bound for leptonion mass comes as

$$m(\pi_L) < \sqrt{\frac{2s_{eff}(e^{10})}{5 + \frac{2}{3}}}m_e \geq \sqrt{\frac{36}{17}}m_e < 2m_e \quad (23)$$

One could argue that some mixing must take place also in charged sector and in minimal scenario one would have $s_{min}(\nu^{10}) = 10$.

b) If $s(\pi_L)$ vanishes as it does for ordinary pion (the p-adic counterpart of PCAC is that pion is massless in order $O(p)$). With this assumption the mass of leptonion is $m(\pi_L) = \sqrt{2/17}m_e \simeq 0.343m_e$, which is by a factor of order 3 smaller than the mass of the observed resonance. In this scenario the decay of $e^- \rightarrow \pi_L^- + \nu_e$ via the emission of virtual W boson becomes possible and world would consist of protons of charged leptonions! Therefore leptonion mass must be larger than m_e and this implies $s(\pi_L) > 1$. The minimal value $s(\pi)_L = 6$ implies $m(\pi_L) \simeq \sqrt{(6 + 2/3)/(5 + 2/3)}m_e$. This is achieved if color binding and spin spin interaction energy contribution satisfies the $|\Delta s| > 18 - 5 = 13$ ($\Delta s = -18$ for pion).

c) Spin spin interaction energy is expected to be much smaller than in hadronic case since it is inversely proportional to the third power of average quark-quark distance. If spin-spin interaction energy vanishes in first order only color Coulombic contribution remains. This contribution is inversely proportional to average quark-quark distance and simple scaling is expected to hold true and $\Delta s_c = -9$ should hold true for leptohadrons, too. With this assumption one obtains

$$m(\pi_L) \simeq \sqrt{\frac{2s_{eff} - 9 + \frac{2}{3}}{5 + \frac{2}{3}}} m_e \quad (24)$$

The observed resonance can be identified as lepton only provided one has $s_{eff}(e^{10}) \geq 15$, which implies that e^{10} suffers at least same amount of mixing as u quark.

d) The alternative identification of resonance as lepto- η is possible if lepton has minimal mass ($s(\pi_L) = 6$ and color magnetic spin-spin interaction is of second order. η mass results from mixing only and if the mixing of η_L is identical with the mixing of η then one has $s(\eta_L) = s(\eta) + s(\pi_L) = 6 + s(\pi_L) \geq 20$, which gives $s(\pi_L) \geq 14$ and requires that topological mixing is large $s_{eff}(e^{10}) \geq 12$. In hadronic case η however mixes with η_c . Even a very small mixing with the leptonic counterpart of η_c could change the mass of η_L considerably since the only possible candidate for the condensation level of lepto-c is $k = 113$. Generalizing from the hadronic case the contribution of $\eta_c^L = c_L \bar{c}_L$ to $s_{eff}(\eta)$ is of order

$$\begin{aligned} \Delta s &= p \cdot s(\eta_c^L) \\ s(\eta_c^L) &\simeq 2s(c_L)12^{14} = 24 \cdot 2^{14} \\ s(c_L) &= 12 \text{ (no topological mixing)} \end{aligned} \quad (25)$$

Correct order of magnitude corresponds to $\Delta s \leq 11$ and this is achieved with extremely small mixing fraction $p \simeq 2^{-15}$.

2.5 Experimental signatures of leptonhadrons

The couplings of leptomeson to electroweak gauge bosons can be estimated using PCAC and CVC hypothesis [Itzykson-Zuber]. The effective $m_{\pi_L} - W$ vertex is the matrix element of electroweak axial current between vacuum and charged leptomeson state and can be deduced using same arguments as in the case of ordinary charged pion

$$\langle 0 | J_A^\alpha | \pi_L^- \rangle = K m(\pi_L) p^\alpha \quad (26)$$

where K is some numerical factor and p^α denotes the momentum of lepton. For neutral lepton the same argument gives vanishing coupling to photon by the conservation of vector current. This has the important consequence that lepton cannot be observed as resonance in e^+e^- annihilation in single photon channel. In two photon channel lepton should appear as resonance. The effective interaction Lagrangian is the 'instanton' density of electromagnetic field [Pitkänen₁, Pitkänen and Mähoenen] giving additional contribution to the divergence of the axial current and was used to derive a model for lepton production in heavy ion collisions.

2.5.1 Leptohadrons and lepton decays

The lifetime of the resonances decaying to e^+e^- pair (neutral lepton) is known to be of order 10^{-10} seconds: the estimate of lifetime [Pitkänen and Mähoenen, Pitkänen₁] using generalization of PCAC hypothesis is of same order of magnitude. A rough estimate for the lifetime of charged lepton is obtained by scaling the life time of the ordinary charged pion, which is proportional to $m(\pi)^3$: this gives value $\tau(\pi_L^-) \sim 10^{-2}$ seconds. If lepton mass is very near to electron mass its decay is phase space suppressed and factor increasing the life time appears. In any case leptons are practically stable particles and can appear in the final states of particle reactions. In particular, lepton atoms are possible and by Bose statistics have the peculiar property that ground state can contain many leptons.

Lepton decays $L \rightarrow \nu_\mu + H_L$, $L = e, \mu, \tau$ via emission of virtual W are kinematically allowed and an anomalous resonance peak in the neutrino energy spectrum at energy

$$E(\nu_L) = \frac{m(L)}{2} - \frac{m_H^2}{2m(L)} \quad (27)$$

provides a unique test for the leptohadron hypothesis. If lepton is too light electrons would decay to charged leptons and neutrinos unless the condition $m(\pi_L) > m_e$ holds true.

The existence of a new decay channel for muon is an obvious danger to the leptohadron scenario: large changes in muon decay rate are not allowed. a) Consider first the decay $\mu \rightarrow \nu_\mu + \pi_L$ where π_L is on mass shell lepton. Lepton has energy $\sim m(\mu)/2$ in muon rest system and is highly

relativistic so that in the muon rest system the lifetime of leptopion is of order $\frac{m(\mu)}{2m(\pi_L)}\tau(\pi_L)$ and the average length traveled by leptopion before decay is of order 10^8 meters! This means that leptopion can be treated as stable particle. The presence of a new decay channel changes the lifetime of muon although the rate for events using $e\nu_e$ pair as signature is not changed. The effective $H_L - W$ vertex was deduced above. The rate for the decay via leptopion emission and its ratio to ordinary rate for muon decay are given by

$$\begin{aligned}\Gamma(\mu \rightarrow \nu_\mu + H_L) &= \frac{G^2 K^2}{2^5 \pi} m^4(\mu) m^2(H_L) \left(1 - \frac{m^2(H_L)}{m^2(\mu)}\right) \frac{(m^2(\mu) - m^2(H_L))}{(m^2(\mu) + m^2(H_L))} \\ \frac{\Gamma(\mu \rightarrow \nu_\mu + H_L)}{\Gamma(\mu \rightarrow \nu_\mu + e + \bar{\nu}_e)} &= 6 \cdot (2\pi^4) K^2 \frac{m^2(H_L)}{m^2(\mu)} \frac{(m^2(\mu) - m^2(H_L))}{(m^2(\mu) + m^2(H_L))}\end{aligned}\quad (28)$$

and is of order $.93K^2$ in case of leptopion. As far as the determination of G_F or equivalently m_W^2 from muon decay rate is considered the situation seems to be good since the change introduced to G_F is of order $\Delta G_F/G_F \simeq 0.93K^2$ so that K must be considerably smaller than one.

Leptohadrons can appear also as virtual particles in the decay amplitude $\mu \rightarrow \nu_\mu + e\nu_e$ and this changes the value of muon decay rate. The correction is however extremely small since the decay vertex of intermediate off mass shell leptopion is proportional to its decay rate.

2.5.2 Leptopions and beta decay

If leptopions are allowed as final state particles leptopion emission provides a new channel $n \rightarrow p + \pi_L$ for beta decay of nuclei since the invariant mass of virtual W boson varies within the range ($m_e = 0.511 \text{ MeV}$, $m_n - m_p = 1.293 \text{ MeV}$). The resonance peak for $m(\pi_L) \simeq 1 \text{ MeV}$ is extremely sharp due to the long lifetime of the charged leptopion. The energy of the leptopion at resonance is

$$E(\pi_L) = (m_n - m_p) \frac{(m_n + m_p)}{2m_n} + \frac{m(\pi_L)^2}{2m_n} \simeq m_n - m_p \quad (29)$$

Together with long lifetime this leptopions escape the detector volume without decaying (the exact knowledge of the energy of charged leptopion might make possible its direct detection).

The contribution of leptopion to neutron decay rate is not negligible. Decay amplitude is proportional to superposition of divergences of axial and vector currents between proton and neutron states.

$$M = \frac{G}{\sqrt{2}} K m(\pi_L) (q^\alpha V_\alpha + q^\alpha A_\alpha) \quad (30)$$

For exactly conserved vector current the contribution of vector current vanishes identically. The matrix element of the divergence of axial vector current at small momentum transfer (approximately zero) can be evaluated using PCAC hypothesis.

$$q^\alpha A_\alpha = f(\pi) m^2(\pi) \pi \quad (31)$$

relating the divergence to pion field, which gives for the matrix element between nucleon states at zero momentum transfer the estimate

$$\langle p | q^\alpha A_\alpha | n \rangle = -f(\pi) \bar{u}_p \gamma_5 u_n \quad (32)$$

Since leptopion mass q^2 is very small as compared to pion mass this gives estimate for divergence of the axial vector current in the amplitude π_L production rate in neutron decay.

Straightforward calculation shows that the ratio for the decay rate via leptopion emission and ordinary beta decay rate is given by

$$\begin{aligned} \frac{\Gamma(n \rightarrow p + e + \bar{\nu}_e)}{\Gamma(n \rightarrow p + \pi_L)} &= \frac{15K^2\pi^2}{2^3 \cos^2(\theta_c)(1 + 3\alpha^2)0.47} \frac{m(\pi_L)^2 f(\pi)^2 m_n}{\Delta^5} \sqrt{1 - \frac{m^2(\pi_L)}{\Delta^2}} \\ &\simeq 1.5336 \cdot 10^7 K^2 \\ \Delta &= m(n) - m(p) \\ f(\pi) &\simeq 93 \text{ MeV} \end{aligned} \quad (33)$$

where the parameter α [Okun] appears in the matrix element of charged electroweak current

$$\begin{aligned} J_\mu &= \bar{u}_p \gamma_\mu (1 + \alpha \gamma_5) u_n \\ \alpha &\simeq 1.253 \end{aligned} \tag{34}$$

Lepton contribution is smaller than ordinary contribution if the condition

$$K < 10^{-4} \tag{35}$$

is satisfied. This condition implies that the relative contribution to muon decay rate is below 10^{-8} and therefore negligibly small. Clearly, lepton emission can give quite large contribution to neutron decay rate.

3 Scaled up copies of hadron Physics?

TGD suggests the existence of scaled up copies of hadron physics corresponding to the Mersenne primes $M_n = 89, 61, 31, \dots$. The requirement of unitarity forces the existence of Higgs in gauge theories and since there seems to be no room for Higgs in TGD these copies of hadron physics might guarantee unitarity. As already found the increase of color coupling strength implied by the existence of color excited quarks means the end of 'old' QCD and a probable emergence of new QCD.

3.1 The observed top candidate and M_{89} Physics?

The TGD:ish prediction for the top mass for $k = 89$ and $k = 97$ levels and are $m_t(89) \simeq 871 \text{ GeV}$ and $m_t(97) \simeq 54.4 \text{ GeV}$ to be compared with the mass $m_t(obs) \simeq 174 \text{ GeV}$ of the observed top candidate. The study of CKM matrix in previous paper led to the cautious conclusion that only the mass of the experimental top candidate is consistent with CP breaking observed in $K - \bar{K}$ and $B - \bar{B}$ system. A possible resolution of discrepancy is the mixing of condensate levels: observed top corresponds to the actual top, for which small mixing of condensate level $k = 97$ with condensate level $k = 89$ takes place:

$$\begin{aligned}
t &= \cos(\Phi)t_{97} + \sin(\Phi)t_{89} \\
\sin^2(\Phi) &= \frac{m_t^2 - m_t^2(97)}{m_t^2(89) - m_t^2(97)} \sim .036
\end{aligned} \tag{36}$$

The value of the mixing angle is rather small and means that top spends less than 4 per cent of its time on $k = 89$ level. The nice feature of the explanation is that all primes $k = 107, 103, 97$ below $k = 89$ define primary condensation levels for quarks. A much less probable possibility is that the observed top belongs to M_{89} physics and there is top quark to be found with mass 54.4 GeV or 871 GeV .

The anomalies reported in the production rate and decay characteristics of the top candidate might have explanation in terms of M_{89} hadron production [Abe *et al*(1994), Abachi *et al*(1994)] taking place besides the production of $t\bar{t}$ pairs: the more recent data [Abe *et al* (1995), Abachi *et al* (1995)] show still slightly too high production cross section. The point is that u and d quarks of M_{89} hadron physics should have masses quite near to the mass of top candidate. The failure to distinguish between actual top and exotic quarks would lead to anomalous features in production and decay characteristics. M_{89} hadrons hadron physics is obtained in good approximation by scaling the ordinary hadron physics by the ratio $\sqrt{\frac{M_{89}}{M_{107}}}$. This implies QCD Λ , string tension, etc. get scaled by the appropriate power of this factor. If $g = 0$ quark (u or d is in question) one might expect that this quark is observed in the decay of scaled up ρ_{89} or $\omega(89)$ meson (the mass ratio of ω and ρ is 1.02 so that the prediction for the effective $u(89)$ mass does not change appreciably). If one defines top mass as $m(u_{89}) = m(\rho_{89})/2$ one obtains the TGD:eish prediction for its mass as $m(u_{89}) = 512\rho_{107} \simeq 197 \text{ GeV}$, which is about 11 per cent larger than the mass of the top candidate. Defining $u(89)$ mass by scaling the mass of ordinary u quark defined as one third of proton mass one obtains u_{89} mass about 8 per cent too smaller than the mass of top candidate.

meson	m/GeV	baryon	m/GeV
π^0	69.1	p	480.4
π^+	71.5	n	481.0
K^+	252.8	Λ	571.2
K^0	254.8	Σ^+	609.0
η	281.0	Σ^0	610.4
η'	490.5	Σ^-	610.5
ρ	394.2	Ξ^0	673.2
ω	400.9	Ξ^-	676.5
K^*	456.7	Ω^-	856.2
Φ	522		

Table 3. Masses of low lying hadrons for M_{89} hadron physics obtained by scaling ordinary hadron masses by a factor of 512.

There is strong mathematical and physical motivation for M_{89} hadron physics. Higgs particle is absent from TGD:eish Higgs mechanism. Originally Higgs particle was introduced to obtain unitary amplitudes in massive gauge theory. It seems that some particles propagating in loops are needed to achieve unitarity in TGD framework, too. It is not difficult to guess that M_{89} hadrons are the TGD:eish counterpart of Higgs.

3.2 What the New Physics could look like?

M_{89} physics means the emergence of a new condensate level in the hadronic physics. One can visualize M_{89} hadrons as very tiny objects possibly condensed on the quarks and gluons of M_{107} hadron physics. The New Physics begins to reveal itself, when the collision energy is so high that M_{89} hadrons inside quarks and gluons can exist as on mass shell particles (M_{89} hadron inside M_{107} hadron is comparable to a bee of size of one cm in a room of size about 5 meters!). The new Physics at the energies not much above the energy scale of top is essentially the counterpart of ordinary hadron physics at cm energies of the order of ρ/ω meson mass. Therefore M_{89} meson resonances and their interactions described rather satisfactorily by the old fashioned string model with string tension scaled by factor 2^{18} should describe the situation. The electroweak interactions should be in turn describable using generalization of current algebra ideas, such as PCAC and vector dominance model. If

M_{89} hadrons condense on quarks and gluons this physics must be convoluted with the distribution functions of M_{89} hadrons inside quarks and gluons. The resonance structures are partially smeared out by the convolution process.

Although the original identification of top quark candidate as u_{89} and d_{89} is probably not correct it is worth of describing the proposed scenario. The observation that the top candidate decays to b quark via W emission has explanation in this picture although at first this decay seems difficult to understand since topology change $g = 0 \rightarrow g = 2$ seems to be involved.

a) An essential assumption is that the outer boundary of p-adic primary condensation level corresponds is the carrier of quark quantum numbers. This assumption is not in accordance with the original idea that boundary components carrying elementary particle quantum numbers have size of order Planck length and implies that family replication phenomenon is associated with the outer boundary of primary p-adic condensate level. One cannot however exclude this possibility since conformal (and scaling) invariance is basic property of boundary component dynamics.

b) Besides this one must assume that $k = 89$ quarks are condensed on ordinary quarks and gluons to explain the decays of top candidate to b-quark. If the ρ ($I = 1$) or ω ($I = 0$) meson of the New Physics is condensed on b quark or c quark then the disappearance of ρ leaves just b or c quark independently of the reaction mechanism.

c) If there is no preference for condensation level then the decay of M_{89} hadrons takes with same probability via any quark. If the condensation takes place hierarchically then M_{89} quarks of the New Physics prefer to condense on $k = 103$ surface rather than to $k = 107$ then decays to b quark or c quark dominate. The scenario is obviously excluded if top is found to decay mostly to b-quark.

A much more simpler picture is that boundary components carrying quark quantum numbers are much smaller than the size of primary condensate level forces the identification of observed top candidate as actual top and M_{89} Physics can only explain the anomalies in production and decay of top.

Consider next the estimation of the production and decay rates for $\rho(89)$ / $\omega(89)$ and more generally M_{89} mesons. The basic idea is that different condensation levels communicate only via electroweak interactions was already suggested in [Pitkänen_b], where various consequences of Mersenne hierarchy

of Physics were considered. The basic interaction is the emission of electroweak gauge boson followed by the decay of the gauge boson to M_{89} quark pair condensed on ordinary quark or gluon and the reverse of this process. Electroweak gauge boson B can be produced either in $q\bar{q}$ annihilation to gluon plus boson: $q + \bar{q} \rightarrow B + g$ or in Compton scattering $q + g \rightarrow q + B$. Compton scattering dominates in the energies considered. The ratio of $\alpha_{em}/\alpha_s \simeq .046$ implies that about the cross section is about 5 per cent from that for the production of ordinary top quark.

Since low energies are in question at M_{89} level the scaled up version of vector dominance model described in the nice book of Feynmann [Feynmann] should give a satisfactory description for the production of M_{89} mesons via resonance mechanism. The idea is to introduce direct coupling $F_V = m_V^2/g_V$ of photon (or gauge boson) to vector boson (ρ, ω, ϕ). The diagrams describing the production of mesons via decay of vector boson contain vector boson propagator $\frac{1}{p^2 - m_V^2 + im_V \Delta}$ and the production rate is enhanced by a factor $R = 4\pi m_V^2/(\Delta^2 g_V^2)$ in the resonance: the factor should be same in M_{89} physics as in ordinary hadron physics. The ratio $r = \alpha_{em}R/\alpha_s$ gives a rough measure for the ratio of the rates of production for $u(89)$ and ordinary top quark. A rough estimate for what is to be expected is obtained by scaling the results of ordinary hadron physics. The table below gives the estimates for the quantity r and one has $r = 15.1$ for ω . ω is clearly a more probable candidate for the resonance structure observed in Fermilab.

meson	$m/512 \text{ MeV}$	$\Delta/512 \text{ MeV}$	$g_V^2/4\pi$	r
ρ	770	150	2.27	0.52
ω	783	10	18.3	15.1
Φ	1019	4.2	13.3	230.8

Table 4. Scaled up resonance production parameters for ρ, ω and Φ . The last column of the table gives the value of the quantity $r = \alpha_{em}R/\alpha_s$, which should give a measure for the ratio of production rate of $u(89)$ and of the the production of ordinary top quark pair.

The proton of M_{89} physics cannot decay to ordinary quarks if only electroweak interactions are allowed. M_{89} proton is stable unless there is a mechanism for the transfer of fermion number between different levels of topological condensate! A possible TGD:eish mechanism for this transition is topologi-

cal evaporation [Pitkänen_b]. The quarks of M_{89} hadron evaporate coherently (color singletness) from M_{89} condensate level and condenses back to M_{107} level. The understanding of B and D meson masses is also based on the possibility of topological evaporation. In [Pitkänen_b] a model for topological evaporation and condensation based on p-adic length scale hypothesis and dimensional arguments was developed but contains several unnecessary ad hoc assumptions.

An alternative mechanism is based on the idea that different p-adic topologies correspond to different phases and phase transitions changing the value of p are possible. In present case the phase transition changing $k = 89$ topology to $k = 97$ topology starts from small seed of $k = 107$ topology, which grows and fills the entire $k = 89$ hadron volume. Similar phase transition takes place on the primary condensation level of quarks, too. The decay of M_{89} hadrons is described as proceeding via the decay to virtual M_{89} hadrons regarded as super cooled $k = 89$ phase. Virtual M_{89} mesons can decay electroweakly and $k = 89$ baryons suffer eventually phase transition to $k = 107$ phase and resulting ordinary quark gluon plasma decays to ordinary hadrons.

One of the suggested applications of topological evaporation [Pitkänen_b] was the explanation of Centauro type events [Lattes *et al*] in terms slightly different rates for the coherent topological evaporation of quarks and antiquarks, which makes possible the situation, when quarks are in vapour phase and antiquarks in condensate or vice versa. A much simpler description free of ad hoc assumptions seems however to be possible. The point is that virtual M_{89} mesons can decay electroweakly and M_{89} pions produce photon pairs with energies differing widely from the energies of the ordinary pions: thus the anomalously small abundance of ordinary pions. The decay of virtual M_{89} baryons via phase transition to ordinary baryons and mesons.

Topological evaporation provides an explanation for the mysterious concept of Pomeron originally introduced to describe hadronic diffractive scattering as the exchange of Pomeron Regge trajectory [Queen and Violini]. No hadrons belonging to Pomeron trajectory were however found and via the advent of QCD Pomeron was almost forgotten. Pomeron has recently experienced reincarnation [Derrick *et al*, Schlein, Smith *et al*]. In Hera [Derrick *et al*] $e - p$ collisions, where proton scatters essentially elastically whereas jets in the direction of incoming virtual photon emitted by electron are observed.

These events can be understood by assuming that proton emits color singlet particle carrying small fraction of proton's momentum. This particle in turn collides with virtual photon (antiproton) whereas proton scatters essentially elastically. The identification of the color singlet particle as pomeron looks natural since pomeron emission describes nicely diffractive scattering of hadrons. Analogous hard diffractive scattering events in pX diffractive scattering with $X = \bar{p}$ [Schlein] or $X = p$ [Smith *et al*] have also been observed. What happens is that proton scatters essentially elastically and emitted pomeron collides with X and suffers hard scattering so that large rapidity gap jets in the direction of X are observed. These results suggest that Pomeron is real and consists of ordinary partons.

The TGD:eish identification of Pomeron is very economical: Pomeron corresponds to sea partons, when valence quarks are in vapour phase. In TGD inspired phenomenology events involving Pomeron correspond to pX collisions, where incoming X collides with proton, when valence quarks have suffered coherent simultaneous (by color confinement) evaporation into vapour phase. System X sees only the sea left behind in evaporation and scatters from it whereas valence quarks continue without noticing X and condense later to form quasielastically scattered proton. If X suffers hard scattering from the sea the peculiar hard diffractive scattering events are observed. The fraction of these events is equal to the fraction f of time spent by valence quarks in vapour phase. In [Pitkänen_b] dimensional arguments were used to derive a rough order of magnitude estimate for $f \sim 1/\alpha = 1/137 \sim 10^{-2}$ for f : f is of same order of magnitude as the fraction (about 5 per cent) of peculiar events from all deep inelastic scattering events in Hera. The time spent in condensate is by dimensional arguments of the order of the p-adic length scale $L(M_{107})$, not far from proton Compton length. Time dilation effects at high collision energies guarantee that valence quarks indeed stay in vapour phase during the collision. The identification of Pomeron as sea explains also why Pomeron Regge trajectory does not correspond to actual on mass shell particles.

The existing detailed knowledge about the properties of sea structure functions provides a stringent test for the TGD:eish scenario. According to [Schlein] Pomeron structure function seems to consist of soft $((1-x)^5)$, hard $((1-x))$ and superhard component (delta function like component at $x = 1$). The peculiar super hard component finds explanation in

TGD:ish picture. The structure function $q_P(x, z)$ of parton in Pomeron contains the longitudinal momentum fraction z of the Pomeron as a parameter and $q_P(x, z)$ is obtained by scaling from the sea structure function $q(x)$ for proton $q_P(x, z) = q(zx)$. The value of structure function at $x = 1$ is non-vanishing: $q_P(x = 1, z) = q(z)$ and this explains the necessity to introduce super hard delta function component in the fit of [Schlein].

To sum up, u_{89} and d_{89} quarks have masses near to top quark mass and production and decay of M_{89} hadrons might explain the reported anomalies in top production and decay. Following list gives some of the unique signatures of New Physics.

- a) At higher energies exotic pions are produced abundantly and might be detectable via annihilation to monoenergetic photon pair. π^0 of the New Physics should have mass 69.1 GeV and $\gamma\gamma$ annihilation width $512 \cdot 7.63 \text{ eV} = 3.9 \text{ MeV}$ (obtained by scaling from that for ordinary pion). The width for the decay by W emission from either quark of $\pi^0(89)$ (the second is assumed to act as spectator) is of order $G_F^2 m(u(89))^5 / (192\pi^3)$ and of order 2.5 MeV .
- b) The scaling of mass splittings inside isopin multiplets with the scale factor 512 as compared to ordinary hadron physics is a unique signature of M_{89} hadrons.
- c) The scaled up versions of ρ and ω meson should be found at nearby energies. Kaon (and s quark) of the New Physics should be seen as a decay product of $\Phi(522 \text{ GeV}) \rightarrow K + \bar{K}$: from table 5. one finds that that Φ should have rather small hadronic width $\Delta \simeq 2.2 \text{ GeV}$ so that the parameter measuring its production rate to the production rate of ordinary quark is as high as $r \simeq 230.8$ at resonance.
- d) Since ω_{89} is superposition of form $u_{89}\bar{u}_{89} - d_{89}\bar{d}_{89}$ half of its decays are of type $d_{89} \rightarrow q + Z^0$ rather than $u_{89} \rightarrow q + W$. There are indeed indications that the decays of the top candidate contain anomalously too large fraction of Z^0 decays whereas W decays are suppressed.

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